

Document made available under the Patent Cooperation Treaty (PCT)

International application number: PCT/AU05/000191

International filing date: 15 February 2005 (15.02.2005)

Document type: Certified copy of priority document

Document details: Country/Office: AU
Number: 2004900769
Filing date: 16 February 2004 (16.02.2004)

Date of receipt at the International Bureau: 28 February 2005 (28.02.2005)

Remark: Priority document submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b)



World Intellectual Property Organization (WIPO) - Geneva, Switzerland
Organisation Mondiale de la Propriété Intellectuelle (OMPI) - Genève, Suisse



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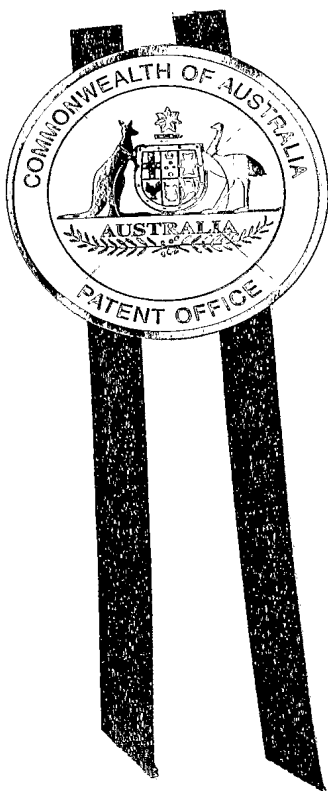
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I, JANENE PEISKER, TEAM LEADER EXAMINATION SUPPORT AND SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. 2004900769 for a patent by KEVIN FRANCIS DOLMAN as filed on 16 February 2004.

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A handwritten signature in cursive script, appearing to read 'J. Peisker'.

JANENE PEISKER
TEAM LEADER EXAMINATION
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AUSTRALIA
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PROVISIONAL SPECIFICATION

Applicant:

KEVIN FRANCIS DOLMAN

Invention Title:

HARDFACING FERROALLOY MATERIALS

The invention is described in the following statement:

HARDFACING FERROALLOY MATERIALS

Introduction

5 The present invention relates to hardfacing
ferroalloy materials containing chromium carbides.

10 Ferroalloy materials containing chromium carbides
have been used extensively for many years as hardfacings
on substrates in applications where resistance to severe
erosion and abrasion is required.

15 One such application is on discharge chutes for
crushers in mineral processing plants.

20 When hardfacings of chromium carbide ferroalloy
materials are formed by welding on substrates, the desired
microstructure for the weld deposits that form the
hardfacings is hypereutectic containing about 30-60
volume% of M_7C_3 carbides in a ferrous matrix ($M = Cr, Fe$
and Mn), a nominal hardness of the M_7C_3 carbides of 1200-
1500 HV, and a nominal hardness of the ferrous matrix of
600-700 HV.

25 In general, higher carbide contents in the
microstructure yield greater wear resistance. There is a
direct correlation between the M_7C_3 carbide content in the
microstructure and the chemically combined carbon content
in the weld metal used to form the hardfacings.

30 The welding consumables for chromium carbide
ferroalloy hardfacings usually comprise a blend of
ferroalloy powders and iron.

35 The ferroalloy powders may be encapsulated in an
iron foil to produce either a stick electrode or a
continuous filler wire which melts in a molten weld pool.

Alternatively, the ferroalloy powders may be added to a molten weld pool formed by a solid iron wire consumable electrode.

5 Typical Prior Art Powder Blend

10 A typical blend of high carbon ferrochromium (HCFeCr) and high carbon ferromanganese (HCFeMn) powders used as welding consumables in the production of a chromium carbide hardfacing is shown in Table 1.

Table 1 Prior Art Ferroalloy Powder Blend

	Weight %	%Cr	%C	%Mn	%Fe
HCFeCr	94	69	8.5		22.5
HCFeMn	6		7.0	75	18.0
Powder Blend	100	64.9	8.4	4.5	22.2

15 The final powder blend set out in Table 1 above, with a chemical composition of Fe-64.9Cr-8.4C-4.5Mn, is made up of 94 weight% HCFeCr (nominal composition = Fe-69Cr-8.5C) mixed with 6 weight% HCFeMn (nominal composition = Fe-75Mn-7.0C).

20

It is evident from the above that the:

Chromium/Carbon ratio of the final powder blend = 64.9/8.4

ie for the Ferroalloy Powder Blend
Cr/C = 7.73

25

Both the HCFeCr and HCFeMn may contain approximately 1% silicon and minor amounts of other trace elements. These constituents are ignored in these

calculations.

Both HCF₂Cr and HCF₂Mn are brittle, friable materials and, in order to form suitable welding consumables, are individually crushed into powders with a particle size less than 1 mm in diameter using standard crushing equipment employed in the mineral processing industry.

The powders are then mechanically mixed to produce a uniform blend of ferroalloy powders.

Other ferroalloy powders such as ferromolybdenum, ferrobore and ferrotitanium may be added to the blend to impart different material properties to the weld pool and to the resultant hardfacing.

Typical Prior Art Hardfaced Weld Deposit

The chemistry of a hardfacing that deposits onto a mild steel substrate from a weld pool containing the blended ferroalloy powders described above is illustrated by way of example in Table 2. The hardfacing is referred to as the "weld deposit" in the Table and hereinafter.

Table 2 Prior Art Hardfacing

	Weight %	%Cr	%C	%Mn	%Fe
Powder Blend	55	64.9	8.4	4.5	22.2
Welding wire	35			1.0	99.0
Dilution	10		0.2	1.0	98.8
Weld Deposit	100	35.7	4.6	2.9	56.8

In the example of Table 2, the weld deposit, ie
hardfacing, on the mild steel substrate is made up of 55
weight% ferroalloy powder blend plus 35 weight% Fe welding
5 wire plus 10 weight% dilution into the substrate.

Dilution of the hardfacing is understood herein
as the depth of penetration into the mild steel substrate
divided by the final height of the hardfacing. For
10 example, a typical 5mm thick hardfacing weld deposit may
penetrate the mild steel substrate to a depth of
approximately 0.5mm during the welding process resulting
in a dilution of 10% (0.5/5.0).

15 The chemistry of the hardfacing in this example
is Fe-35.7Cr-4.6C-2.9Mn. The microstructure comprises
approximately 45 volume% of M_7C_3 carbides in a ferrous
matrix.

20 It is evident from the above that the:

Chromium/Carbon ratio for the Hardfacing = $35.7/4.6$

ie for the Hardfacing Weld Deposit $Cr/C = 7.76$

25 Limitations of the Prior Art

The limitations of the above-described prior art
and other prior art known to the applicant in the
manufacture and use of ferroalloy powders for producing
30 hardfacing weld deposits are:

- The chromium content in the final hardfacing is very
high (35.7%Cr in the above example) compared to the
chromium content in suitable wear resistant white cast
35 irons specified, for example, in ASTM A532 and AS 2027.

- The higher chromium content is a direct result of maximising the amount of combined carbon (4.6%C) in the hardfacing by adding as much ferrochromium powder as possible in the blended welding consumable. That is, excessive amounts of chromium are tolerated in order to maximise the carbon content in the final weld deposit. Adding free carbon powder to the ferroalloy blend in order to increase the carbon content in the final weld deposit is not effective since the free carbon does not readily dissolve in the molten weld pool during the relatively short arc melting time (nominally 2 to 5 seconds) to form hardfacings on substrates.
- Attempts to add other ferroalloys, such as ferrotitanium and ferromolybdenum, to the above powder blend cause an undesirable reduction in the carbon content of the final hardfacing since FeTi and FeMo contain relatively low combined carbon contents.
 - The above-described prior art blend of ferroalloy powders is obtained by mechanically mixing the HCFeCr and HCFeMn powders together. Mechanical mixing is a slow and inefficient means of obtaining a homogeneous powder blend. The degree of difficulty in achieving a homogeneous mixture of the powder blend increases when other ferroalloy powders are included in the mix. In addition, segregation of the blended powders tends to occur on handling after mixing due to density differences between the various ferroalloys.
 - The principal ferroalloy powders in hardfacing weld deposits are obtained by crushing lump HCFeCr and lump HCFeMn which are sourced from suppliers of furnace charge materials that are used for the production of white iron castings. Experience has shown that these materials contain varying amounts of volatile gases, which evolve violently during the welding process

causing arc instability and ejection of some ferroalloy powder from the weld pool. The resultant hardfacings contain gas porosity, varying amounts of ferroally ingredients and varying amounts of dilution into the steel substrate. The final hardfacings are generally not uniform in chemical composition and microstructure and can lead to localised premature wear in service.

Description of the Invention

The present invention is a method of producing improved hardfacings compared to the prior art in a cost-effective manner.

The method has been developed to overcome or at least minimise the four technical disadvantages of chromium carbide hardfacing welding consumables described above than has been used previously.

The present invention is based on the realisation that improved hardfacings can be produced by using a quite different method to produce ferroalloy welding consumables that are required to form the hardfacings.

According to the present invention there is provided a method of producing a chromium carbide-containing ferroalloy welding consumable material for subsequent use for producing a hardfacing on a suitable substrate which comprises:

- (a) forming a homogeneous melt that has a required concentration of key elements, such as carbon and/or chromium, for a chromium carbide-containing ferroalloy welding consumable material; and
- (b) forming a solid chromium carbide-containing

ferroalloy welding consumable material from the melt.

5 Preferably step (a) comprises forming the homogeneous melt from solid feed materials.

Preferably the solid feed materials comprise a chromium-containing ferroalloy material.

10 Preferably the solid feed materials comprise a source of free carbon.

15 Preferably the solid feed materials comprise an iron-containing material (other than a chromium-containing ferroalloy), such as scrap steel, to dilute the chromium concentration in the melt.

20 Preferably the method comprises mixing the melt and forming the homogenous melt during a required time period at temperature so that the solid ferroalloy welding consumable material has a uniform composition.

25 Typically, the solid ferroalloy welding consumable material formed in step (b) comprises a powder.

30 Preferably the method comprises de-gassing the melt so that the solid ferroalloy welding consumable material formed in step (b) facilitates a stable welding arc in a subsequent hardfacing operation and thereby minimises porosity in the resultant hardfacing and eliminates ejection of ferroalloy powder from the weld pool.

35 Preferably the method comprises removing slag from the melt so that the solid ferroalloy welding consumable material formed in step (b) minimises the presence of non-metallic impurities in the resultant

hardfacing formed in the subsequent hardfacing operation.

Preferably the method comprises producing a ferroalloy welding consumable material having a chromium/carbon ratio < 6.67.

Preferably the method comprises producing a ferroalloy welding consumable material having a chromium content of less than 30 weight%.

Preferably the method comprises producing a ferroalloy welding consumable material having a combined carbon content greater than 4.0 weight%

Typically, the method comprises combining and melting ferroalloy feed materials, which may be in lump form, in a suitable melting furnace.

Thereafter, inexpensive scrap steel is added to the melt to lower the amount of chromium in the ferroalloy blend to a level consistent with comparable wear resistant white cast irons.

Free carbon is then added to the melt to supersaturate the melt with free carbon, and the melting furnace is held at temperature during a relatively long holding time (nominally 30 to 60 minutes) to dissolve the carbon in the melt to produce the desired level of combined carbon in the solid ferroalloy welding consumable material from the melt.

Preferably step (b) of forming the solid ferroalloy welding consumable material from the melt comprises casting the melt into a suitable mould(s) or other casting means and thereafter breaking the cast product into a suitable form, such as powder form.

In an alternative, although not the only other, embodiment step (b) of forming the solid ferroalloy welding consumable material from the melt comprises atomising the melt with a suitable gas, such as argon, to
5 form solid powder from the melt.

According to the present invention there is also provided a chromium carbide-containing ferroalloy welding consumable material produced by the above method.

10

According to the present invention there is also provided a method of producing a hardfacing on a suitable substrate which comprises forming a weld pool of the above-described chromium carbide-containing ferroalloy
15 welding consumable material and a welding wire material on a substrate and thereafter depositing a hardfacing of material from the weld pool on the substrate.

According to the present invention there is
20 provided a hardfacing on a suitable substrate produced by the above method.

Preferably the hardfacing comprises a chromium/carbon ratio < 6.67 .

25

Preferably the hardfacing comprises a chromium content of less than 30 weight%.

Preferably the hardfacing comprises a combined
30 carbon content greater than 4.0 weight%.

Table 3 illustrates by way of example the chemistry of a ferroalloy welding consumable material, hereinafter referred to as a "blended ferroalloy
35 material", produced in accordance with the invention.

Table 3 Chemistry of Ferroalloy Powder Blend According to

the Invention

	Weight %	%Cr	%C	%Mn	%Fe
HCFeCr	67	69.0	6.0		25.0
HCFeMn	7		7.0	75.0	18
Steel Scrap	22		0.2	1.0	98.8
Carbon	4		100.0		
Final Blend	100	46.2	8.6	5.5	39.7

Note:

5

- Scrap steel (22 weight%) is alloyed into the liquid metal to lower the chromium content of the final blend.

10

- The chromium content of the ferroalloy blend is reduced from 64.9% in the prior art ferroalloy powder blend (Table 1) to 46.2% in the blend of the present invention (Table 3).

15

- 4 weight% free carbon is dissolved in the liquid metal to increase the combined carbon content of the final blend.

20

- HCFeCr feed material containing relatively low carbon contents (eg. 6.0% C) can be used rather than more expensive HCFeCr feed material containing higher carbon contents (eg. 8.5% C) used in the known ferroalloy powder blend in Table 1.

25

- HCFeCr feed material containing relatively low chromium contents (eg. 55% Cr) can be used rather than more expensive HCFeCr feed material containing higher chromium contents (eg. 69% Cr) used in the known

ferroalloy powder blend in Table 1.

- The chemical composition of the final ferroalloy blend is Fe-46.2Cr-8.6C-5.5Mn. This material is brittle and friable and is readily reduced to a fine powder by crushing in the usual manner.

Chromium/Carbon ratio of the Blended Powder = 46.2/8.6

ie for the Ferroalloy Powder Blend Cr/C = 5.37

10

There are other practical advantages achieved by the method of producing ferroalloy welding consumables according to the invention.

15

The alloying materials are very efficiently mixed in the molten state to produce a more homogeneous ferroalloy blend than that achieved by mechanically mixing ferroalloy powders as described in the prior art. Segregation of the premixed ferroalloy powder does not occur on subsequent handling.

20

All volatiles present in the lump ferroalloy materials fully outgas during the melting process and this eliminates a major source of gas porosity in the final weld metal and improves the stability of the welding arc during the weld deposition process.

25

Non-metallic impurities present in the charge materials are readily removed by de-slagging the molten metal in the furnace with suitable fluxing agents.

30

The chemistry of the final hardfacing weld deposit using the new ferroalloy blend as described in this invention is illustrated in Table 4 by way of example.

35

Table 4 Chemistry of Hardfacing Weld Deposit According to the Invention

	Weight %	%Cr	%C	%Mn	%Fe
Powder	55	46.2	8.6	5.5	39.7
Welding wire	35			1.0	99.0
Dilution	10		0.2	1.0	98.8
Weld Deposit	100	25.4	4.8	3.5	66.3

Note:

- The chromium content of the weld deposit has been reduced from 35.7%Cr for the prior art processes (Table 2) to 25.4%Cr for the present invention without reducing the carbon content.
- The microstructure of the final weld deposit comprises 45 volume percent M_7C_3 carbides.
- The ratio of welding consumables and amount of dilution is identical with Table 2, ie there are no changes required in the hardfacing welding procedure used in the prior art.

Chromium/Carbon ratio for the Hardfaced Weld Deposit = $25.4/4.8$

ie for the Hardfaced Weld Deposit
 $Cr/C = 5.29$

Many modifications may be made to the embodiments of the present invention described above without departing

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from the spirit and scope of the invention.